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EXPERIMENTS IN FEEDING FOR MILK.

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EXPERIMENTS IN FEEDING FOR MILK.

BY CHAS E. THORNE, J. FREMONT HICKMAN AND F. J. FALKENBACH.

I.—CORN SILAGE VS. FIELD BEETS AS FOOD FOR MILK PRODUCTION.

In the Bulletin of this Station for June, 1889, is reported an experiment in the comparative feeding of corn silage and field beets to dairy cows, twelve cows being used in the experiment, which continued eight weeks. In this experiment there was apparently a greater production of milk while the cows fed on beets, but a greater increase of live weight while they fed on silage.

The experiment was repeated the following winter, twelve cows again being put under test over a period of ten weeks. The results of this test were given in the Bulletin for June, 1890. Briefly stated, the cows not only gave more milk on the average, but also showed a greater average increase in live weight while feeding on beets than on silage.

During each of the next two winters the experiment was repeated, with sixteen cows under test in each case. Following is a detailed report of these tests:

EXPERIMENTS OF 1891 AND 1892.

Sixteen cows were selected for each of these tests from the herd of thirty or more belonging to the Station, eight of which were registered Jerseys and eight were grades, chiefly high-grade Short-horns. These cows were divided as before into four lots, a, b, c and d, each lot containing two grades and two Jerseys. Further data respecting the cows are given in Tables I and II:

TABLE I.—DATA CONCERNING COWS UNDER TEST IN 1891.

Lot.	Cow.	Age—Yrs	Breed.	Date of last calving.
A	No 1	7	Short horn grade	June 3, 1890.
	No 9	9	Short-horn grade	October 16, 1890.
	Myrtle Bacon, 46,669	6	Jersey	October 31, 1890.
	Lady Lyle, 9,498	13	Jersey	September 16, 1890.
B	No. 20	7	Short-horn grade	December 7, 1890.
	No. 14	9	Short-horn Jersey	October 8, 1890.
	Cedrica Bacon, 49,407	5	Jersey	May 30, 1890.
	Madge Page, 47,395	5	Jersey	October 2, 1890.
C	No 5	7	Short-horn grade	October 1, 1890.
	No. 24	5	Devon-Jersey	December 10, 1889.
	Lyline, 47,398	4	Jersey	December 3, 1890.
	Regia Bacon, 47,399	4	Jersey	September 28, 1890.
D	No. 21	9	Short-horn grade	October 27, 1890.
	No 8	6	Short-horn grade	July 17, 1890.
	Deletta, 46,764	4	Jersey	November 29, 1890.
	Misty May, 46,765	4	Jersey	September 16, 1890.

TABLE II.—DATA CONCERNING COWS UNDER TEST IN 1892.

Lot.	Cow.	Age—Yrs.	Breed.	Date of last calving.
A	No. 25	7	Short-horn grade	October 1, 1891.
	No. 9	10	Short-horn grade	October 27, 1891.
	Myrtle Bacon, 46,669	7	Jersey	November 26, 1891.
	Regia Bacon, 47,399	5	Jersey	July 12, 1891.
B	No 20	8	Short-horn grade	December 2, 1891.
	No 26	6	Short-horn grade	October 1, 1891.
	Cedrica Bacon, 49,407	6	Jersey	August 26, 1891.
	Madge Page, 47,395	6	Jersey	August 28, 1891.
C	No 13	9	Short-horn grade	May 1, 1891.
	No 24	6	Devon-Jersey	October 27, 1891.
	Lyline, 47,398	5	Jersey	December 20, 1891.
	Etta's Pride, 47,400	5	Jersey	March 17, 1891.
D	No 21	10	Short-horn grade	October 12, 1891.
	No. 8	7	Short-horn grade	September 10, 1891.
	*Deletta, 46,764	5	Jersey	October 13, 1891.
	Bacon Maid, 47,397	5	Jersey	June 1, 1891.

*Deletta became sick during the test and was withdrawn near its close, hence the calculations of food and product for lot D in 1892 are based upon the records of the other three cows only.

In each experiment, lots A and B were alternated with lots C and D, lots A and B receiving beets as part of their ration for a period of three weeks, while lots C and D had silage, and *vice versa* The treatment of lots A and B and of C and D differed only in the kind of meal fed, lots A and C receiving daily six pounds of corn meal, while lots B and D received instead a mixture of three pounds each of wheat bran and old process linseed oil meal, these meal rations being continuous throughout the experiment.

In 1891 the actual test began February 10th and ended April 13th, extending over three periods of three weeks each; but this was preceded by a period of three weeks in which the cows were gradually accustomed to the feeding stuffs to be used in the experiment. The supply of beets was exhausted at the end of the first week of the third period, and for the remaining two weeks silage was substituted, so that we have in the case of lots A and B only one period of full feeding on beets to compare with one on silage, while lots C and D had one period of beet feeding between two periods of silage feeding.

In 1892 the preliminary feeding began January 9th and the actual test ten days later, but owing to a misunderstanding on the part of the feeders full records were not kept for the 19th, 20th and 21st, hence the first period contains only 18 days, the remaining periods extending over three full weeks each.

The cows were milked twice each day by the same men and in the same order. The hay and meal were fed morning and evening only, but the silage and beets were given in three feeds, morning, noon and night. At about ten o'clock each morning the cows were weighed, then allowed to drink from a tub of water standing on scales, by which means the amount drank was determined, then on fair days they were turned out of doors until one o'clock P. M.

Following is the percentage of total dry matter* in the various feeding stuffs used, being in most cases the average of several determinations:

TABLE III.—TOTAL DRY MATTER IN FEEDING STUFFS.

1891.	Per cent	1892.	Per cent.
Clover hay	93.05	Blue grass hay	94 03
Corn silage	24.75	Corn silage	27 92
Mangels	11.80	Mangels	9.60
Corn meal	84.60	Corn meal	84.60
Bran	90 35	Bran	90.35
Linseed oil meal	92 54	Linseed oil meal	92.54

*By "dry matter" is meant the absolutely dry product obtained by drying the material for several hours at a temperature of 212° Fah.

Separate determinations were not made of the bran and meals for the two experiments, but as uniform lots were used throughout each experiment and the rations were identical in both tests, the comparison is not affected.

Had the cows consumed the same quantity of hay while feeding on beets as on silage they would have received a little more dry matter in the silage than in the beet ration; but they ate a decidedly larger quantity of hay while eating beets, and this has been our uniform experience in feeding beets. They increase the appetite for other foods.

THE SILAGE.

The silage was made from Indian corn, so grown as to produce considerable grain, and preserved in good condition. That used in 1891 was made from corn planted June 7th and harvested September 23d to October 4th, when most of the fodder was quite dry and the corn was ripe enough to shock without danger of spoiling. The per cent. of corn on the cob found in this silage averaged 17½ equivalent to about 14 per cent. actual grain.

The corn used in the experiment of 1892 was planted May 30th and harvested September 26th to October 3rd, and was put into the silo in riper condition than in any previous season. An average of 16 per cent. of ear corn was found in the silage, equivalent to about 13 per cent. actual grain.

The silage was fed at the rate of 30 pounds per cow per day, in three equal feeds, morning, noon and night. In 1891 it was eaten clean by half the cows, and the quantity refused by others was comparatively small; but in 1892 no cow ate her silage clean throughout both periods of the test.

Determinations of dry matter in the silage indicated an average of 24.75 per cent. in 1891 and 27.92 per cent. in 1892. The cows ate an average of 28.71 pounds per cow per day in 1891 and 24.82 pounds per day in 1892. The actual dry matter consumed in silage was 7.11 pounds per cow per day in 1891 and 6 94 pounds per day in 1892, a daily difference of 0.17, or one-sixth of a pound.

In the last experiment five or six determinations of the percentage of grain in the silage were made during each period, and these show the following averages. Period I, 13½; period II, 16, period III, 18; period IV, 17½ Lots A and B received silage during periods I and III, and ate an average of 25.24 and 21.25 pounds per cow per day Lots C and D received silage during periods II and IV, and ate an average of 27.65 and 25.15 pounds per cow per day. In both cases, therefore, the quantity eaten was in inverse ratio to the amount of grain in the silage. The

larger quantity of grain in the silage indicates a closer approach to the conditions of ordinary field culture of corn, other things being equal, conditions which produce a comparatively large proportion of coarse stalks, and it was these stalks which the cows rejected. Theoretically, this waste would be expected to be partly offset by the superior quality of the silage containing the most grain, and previous experiments indicate that silage containing a low percentage of grain has a relatively low feeding value, but there would seem to be a middle ground worth striving for.

It is not forgotten that the smaller consumption of silage occurred later in the season, when other factors, such as increased temperature of the air and increased age of the silage may have operated to check the cows' appetite for it; but in the experiment of 1891, which ended on practically the same date as that of 1892, nearly all the silage was eaten, and in that of 1890, ending two weeks later, all the silage was eaten throughout the test. The experiment of 1889 began March 1st and ended April 27th; the cows received 40 pounds of silage per head per day, and ate the quantities indicated below:

TABLE IV.—POUNDS OF SILAGE CONSUMED PER COW PER DAY IN 1889.

Lot	Period I March 1–14.	Period II. March 15–28.	Period III March 29–April 13	Period IV April 14–27.
A....	35 6	36.5	36 2	33 7
C...	38.3	. ...	37.3	....
D...	..... .	35 0	....	35 2

In this experiment lot A was fed on silage and lot B on beets throughout the test, lots C and D being fed in alternating periods. No estimate was made of the percentage of grain in the silage, but the corn was more mature when put into the silo than in 1890. That used in 1890 was not planted until June 19th and 20th. In this experiment the lot continuously fed on silage consumed a smaller quantity during the latest period of the test, but in the case of the alternating lots the difference is not sufficient to justify the assumption that the silage was less palatable then than earlier.

As the matter stands, the question of the state of maturity in which silage corn should be harvested seems worthy of further investigation.

THE BEETS.

In the experiment of 1889 the cows rejected on the average ten per cent. and in that of 1892 six per cent of the total silage fed; but in both tests there were individual cows which refused a much larger proportion, whereas beets have been eaten by so nearly every cow to which we have ever fed them that the exceptions amount to nothing. In the two experiments now under consideration, less than one bushel of beets was refused out of more than a thousand fed, and this was all refused by one cow in 1891.

The beets were of the "long red" variety of mangels. Those grown for the test of 1891 were planted May 5th on timothy sod and harvested October 24th to 26th inclusive; and those grown for the test of 1892 were planted May 3d, on land dressed with barnyard manure at the rate of sixteen tons per acre before plowing, and were harvested October 25th to 30th. Those grown in 1890 showed an average of 11.8 per cent. of dry matter, and in 1891, 9.6 per cent.

THE HAY.

Clover hay was fed in the experiment of 1891, and hay made from Kentucky blue grass, cut from the College lawn early in June, in 1892. The clover hay showed 93.05 per cent. dry matter and 12.25 per cent. protein, the blue grass hay 94.03 per cent. dry matter and 8.01 per cent. protein. In 1891 the cows ate an average of 17.00 pounds hay per cow per day while on beets and 12.54 pounds while on silage, and in 1892 they ate 17.50 pounds per day while on beets and 11.52 pounds while on silage.

It was part of the plan of the experiment that all the cows should receive more hay than they could eat, and that the uneaten residuum should be weighed back and thrown away or fed to other stock. This plan was fairly executed in 1891, but in 1892 several of the cows in lots A and B manifested a dislike for the silage, and in order to induce them to eat more of it their hay ration was restricted while on silage. They were so fed, however, that there was always a considerable uneaten residuum of either hay or silage. Lots C and D ate the silage fairly well, and always left some hay in their mangers, and all the cows were so fed that there was hay left while on the beet rations; but to accomplish this it was necessary to feed a much larger quantity of hay while on beets than on silage.

FOOD CONSUMED.

The following table shows the average amount of food consumed per cow per day by the alternating lots:

TABLE V—POUNDS OF FOOD CONSUMED.

Lots.	Food.	1891.				1892.			
		Period.				Period			
		0	I	II	III	I	II	III	IV
A & B	Hay	12 72	17 80	16 23	14 31	11.40	17.82	12 34	16 75
	Silage	.....	.....	28 42	.....	25.24	.....	21 25	.....
	Beets	.....	50.00	.....	.....	.....	50 00	.... ..	50.00
	Meals	6 00	6 00	6.00	6 00	6 00	6 00	6 00	6.00
	Total dry matter	.....	27.74	27.41	.....	23.05	26.83	22.82	25.83
C & D	Hay	9.68	11 47	16 21	9 92	18 01	11.41	17.43	10.93
	Silage	.....	28.57	.....	29 14	.....	27.65	.....	25.15
	Beets	.....	.... .	49 50	.....	50.00	.....	50.00	.....
	Meals	6.00	6.00	6.00	6.00	6 00	6.00	6.00	6 00
	Total dry matter	.....	23.02	26 23	21 72	26 84	23.70	26.44	22.55

* Corn meal, or bran and oil meal. See *ante*.

It will be observed that in every case the average consumption of hay and of total dry matter has been greater when beets were being fed than during the periods of silage feeding. The only case in which the difference was not very decided was in period II of 1891, when the margin was small, and when several cows reversed the rule which has at other times prevailed almost without exception. The only explanation we can offer for this exception is that during this period all the cows manifested an increased appetite, gave a larger flow of milk and gained in live weight. Reference to the charts which follow will show that this was a period of rising temperature and moderate fluctuations of the barometer. The records of the Station's Meteorologist for that period (March 3–23) show that rain fell on twelve of the twenty-one days.*

In the general average the cows consumed in 1891, 26.98 pounds of dry matter per cow per day while on beets and 24.89 pounds while on silage, and in 1892, 26.48 pounds while on beets and 23 03 pounds while on silage.

YIELD OF MILK AND BUTTER FAT.

In the following table is given the average yield in pounds of milk and butter fat for the alternating lots:

* In the annual report of the Wisconsin Agricultural Experiment Station for 1892, page 67, is reported a similar increase in flow of milk under similar conditions of weather.

TABLE VI—YIELD OF MILK AND BUTTER FAT PER COW PER DAY.

Lots.	Product.	1891. Period and food. 0	1891. I. Beets.	1891. II. Silage	1891. III.	1892. Period and food. I. Silage	1892. II. Beets	1892. III. Silage	1892. IV. Beets.
		Lbs.	*Lbs.*	*Lbs*	*Lbs*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs*
A & B	Milk	17.56	17.50	18 07	17.66	17.90	18 02	17.57	18 04
	Butter fat	.644	.616	571	.594	.797	.780	.761	.771
			Silage	Beets	Silage	Beets.	Silage	Beets	Silage
C & D	Milk	14.92	14 70	15 76	15.07	19 38	17.30	18 01	17 07
	Butter fat	.589	.580	.598	610	883	.800	.839	.716

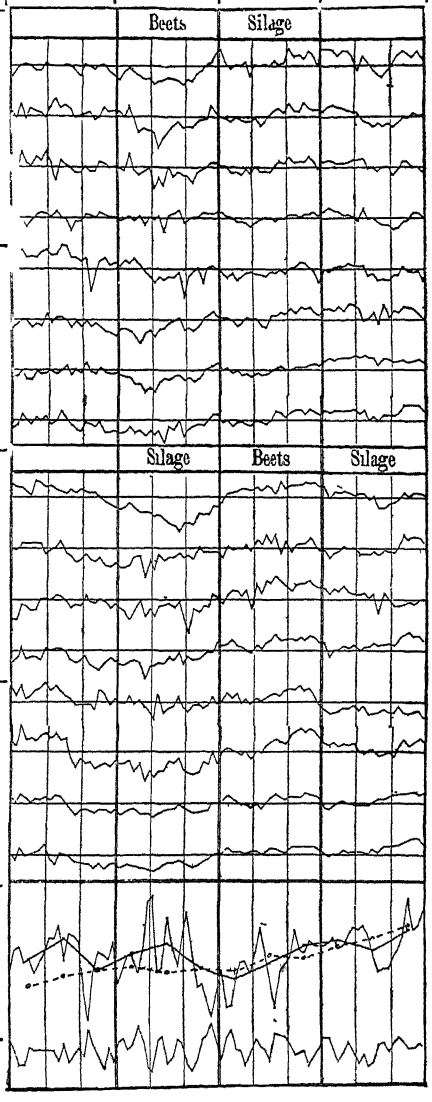
In 1891 the average yield of milk from 16 cows was 16 63 pounds, per cow per day while feeding on beets and 16.48 pounds while on silage, and in 1892 it was 18.36 pounds while on beets and 17.46 pounds while on silage, a gain of 0.15 pound of milk per cow per day for the beet ration in 1891 and 0.90 pound per day in 1892. In 1890 the increased flow of milk on the beet ration was found to average 1.34 pound per cow per day and in 1889 0.24 pound. The average yield and daily variations in flow of milk are graphically shown in diagrams I and II.

The percentage of butter fat was determined once each week by Babcock's test. In the average milk from all the cows 3.656 per cent. of fat was found in 1891 while the cows were feeding on beets and 3 5.2 per cent. while on silage, and in 1892, 4 455 per cent. on beets and 4.404 per cent. on silage.* The average total butter fat found in the milk per cow per day in 1891 was .607 pounds while the cows fed on beets and .587 pounds on silage, and in 1892 it was 818 pounds on beets and .769 on silage. The test would have been more satisfactory had the fat determinations been made daily; but they indicate that the percentage of fat in the milk was not materially affected by the feed, but that the total quantity of fat varied approximately with the flow of milk, and this was undoubtedly increased by the beets.

*In our first experience with the Babcock test our readings were too low, owing to an error in manipulation This error, however, does not affect the comparison here made, since it runs uniformly throughout the experiment of 1891. The readings of 1892 are believed to be correct.

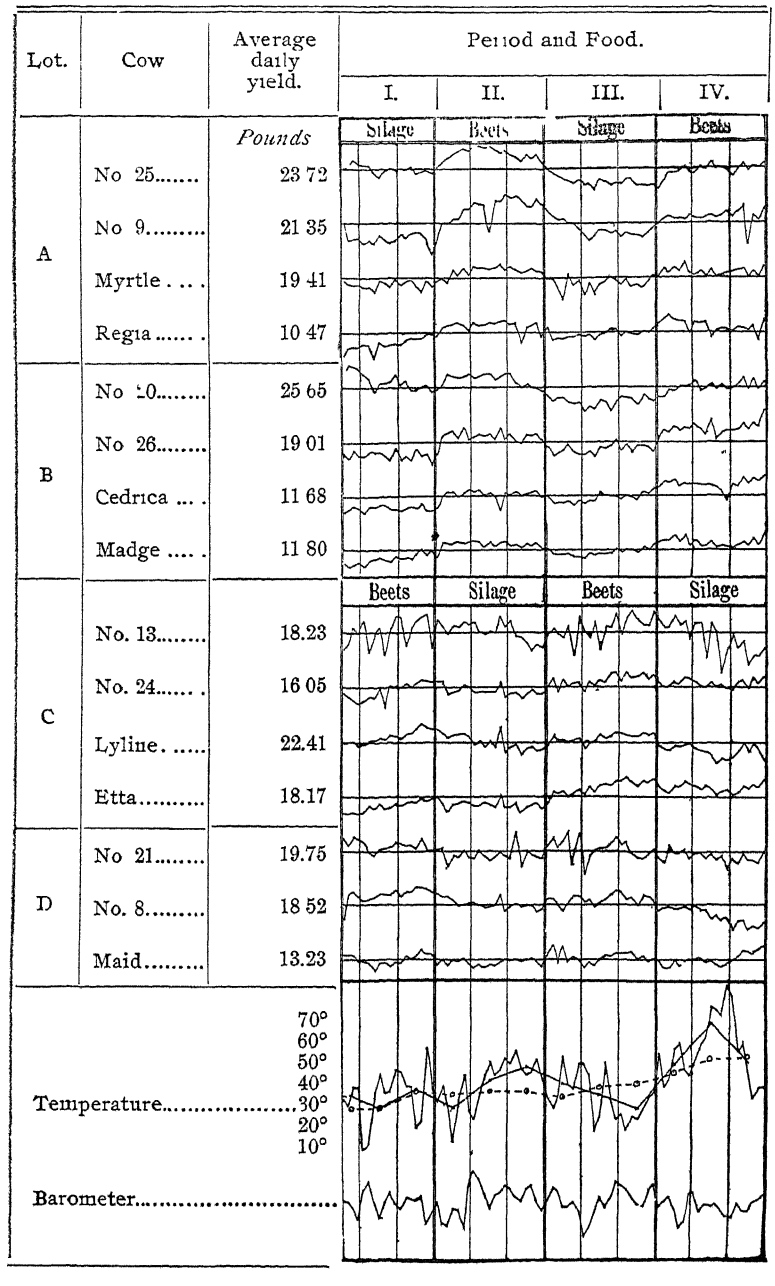
DIAGRAM I—AVERAGE YIELD AND DAILY VARIATIONS IN MILK FLOW IN EXPERIMENT OF 1891.

Lot.	Cow	Average daily yield.
		Pounds
A	No. 1.	24 45
	No 9	22 49
	Myrtle ..	18 43
	Lady.	9 30
B	No 20.	24 82
	No 14.	18 39
	Cedrica	13 84
	Madge	9 88
C	No 5	20 74
	No 24	15.97
	Lyline	14 74
	Regia . ..	8.34
D	No 21	21.02
	No 8	19 86
	Deletta.....	10 06
	Misty	10.60



*The continuous lines indicate the daily variations and weekly means in temperature; the dotted lines the ten years' average

DIAGRAM II—AVERAGE YIELD AND DAILY VARIATIONS IN MILK FLOW IN EXPERIMENT OF 1892.



RATIO OF DRY MATTER IN FOOD TO YIELD OF MILK.

It is evident that the feeding of beets uniformly tends to increase the flow of milk; but it has also been shown that beets increase the consumption of other foods, and this raises the question whether the beets increase or diminish the actual effectiveness of the food. This question can only be answered by reducing all the foods to the basis of dry matter and then comparing the results. On this basis we find that in 1891 the sixteen cows produced 62 pounds of milk for each hundred pounds of dry matter consumed in the beet ration, against 66 pounds of milk per hundred of dry matter in the silage ration, and in 1892 they produced 69 pounds and 76 pounds of milk, respectively, per hundred of dry matter in the two rations. In the experiment of 1890, which showed the largest increase in milk on the beet ration, the milk production for one hundred pounds of dry matter was 59 pounds on beets and 60 pounds on silage. In the experiment of 1889 the first period of beet feeding should be excluded, as the progress of the experiment showed that the cows did not have all the hay they would have eaten during this period. Excluding it, the production of milk for the two alternating lots averaged 59 pounds on beets and 62 pounds on silage. Thus it appears that in the general average of all these experiments a hundred pounds of dry matter has produced about four pounds, or approximately six per cent. more milk when the cows were feeding on silage than on beets.

EFFECT UPON LIVE WEIGHT.

In the experiment of 1891 the daily weight of the sixteen cows averaged 852 pounds while feeding on beets and 849 pounds while feeding on silage. In 1892 these weights were 974 and 960 pounds respectively. In 1890 the average daily weight of the six cows fed in alternating lots was 996 pounds while on beets and 978 pounds while on silage, and in 1889 the corresponding weights were 1,104 pounds and 1,100 pounds. In the average of the four tests the live weight was 950 pounds while on beets and 941 pounds while on silage. In every test there was a marked increase in weight when the cows were changed from silage to beets, and a marked decrease when the opposite change was made. An examination of diagrams III and IV, and of the similar diagrams published in the report of the experiment of 1890, will show that in most cases these fluctuations in live weight began immediately upon the change of feed, thus indicating that they may have been due, in part at least, to the increased weight of the food and water taken with the beets, which will be referred to further on. It will be observed, however, that in the majority of cases the cows continued to increase in weight while feeding on beets, and were heavier during the last week of the period than during the first; this happened in 32 out of the 48 individual cases, whereas in the 56 individual cases of silage feeding the cows showed a gain in but 24 cases. There were four cases of slight loss in weight while feeding on beets and

sixteen similar cases while on silage. If, however, we exclude the first week of each silage-feeding period to allow the contents of the digestive tract to resume their normal weight, we find that in 33 cases the average live weight was greater during the third week than during the second, and in 12 cases it was less.

DIAGRAM III.—AVERAGE LIVE-WEIGHT AND DAILY FLUCTUATIONS IN EXPERIMENT OF 1891.

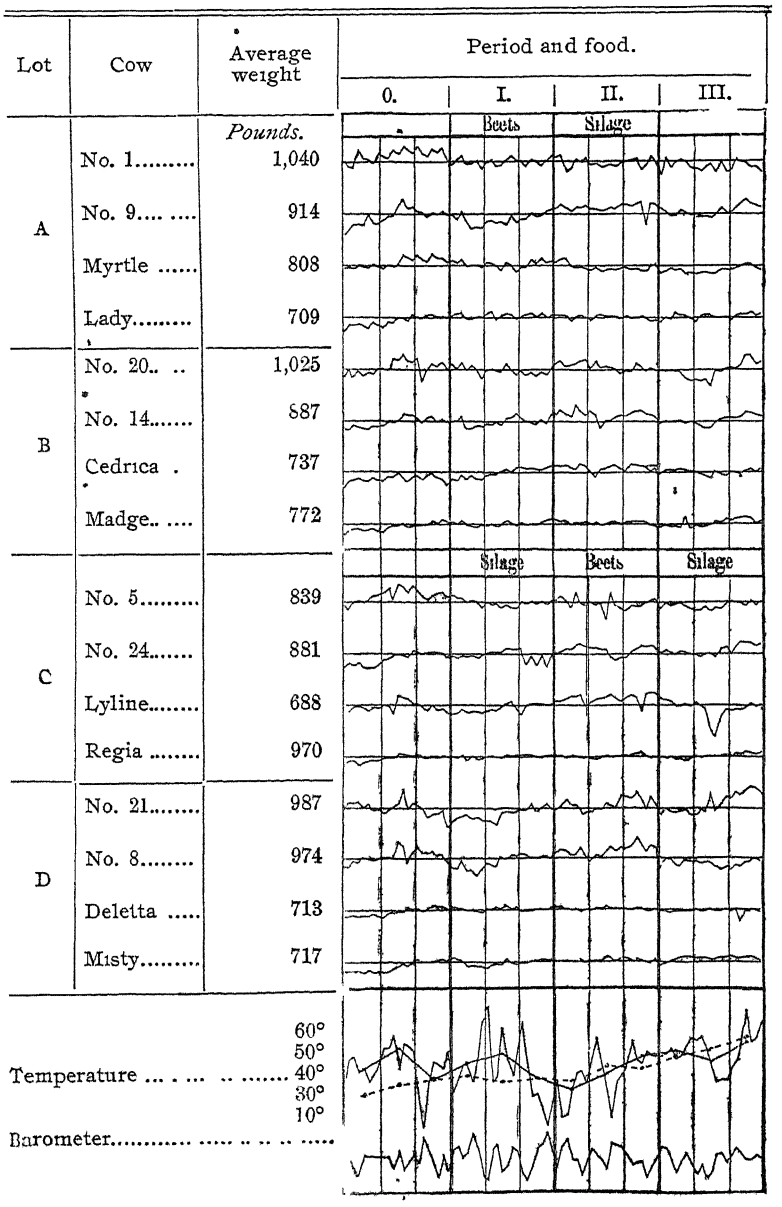
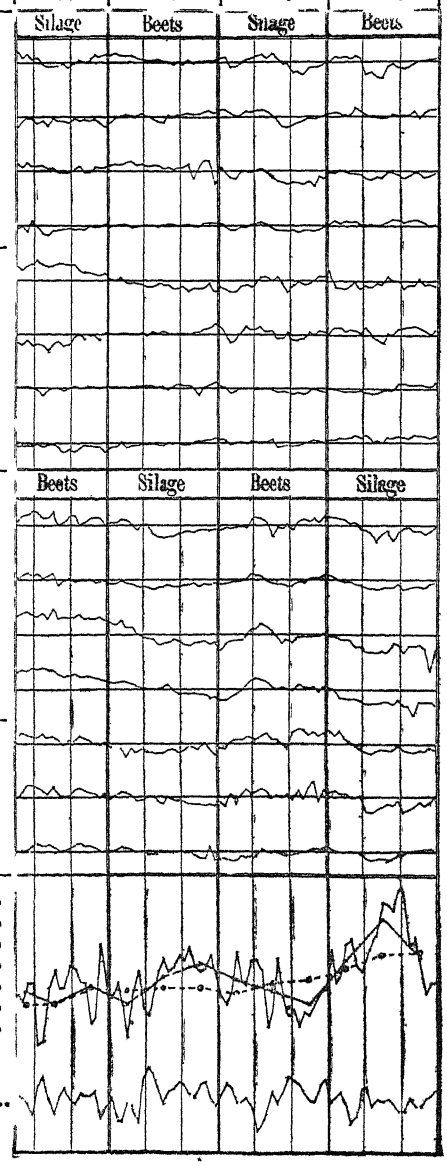


DIAGRAM IV.—AVERAGE LIVE-WEIGHT AND DAILY FLUCTUATIONS IN EXPERIMENT OF 1892

Lot.	Cow.	Average weight
		Pounds.
A	No. 25	1,020
	No. 9	999
	Myrtle	861
	Regia	996
B	No. 20	1,103
	No. 26	1,085
	Cedrica	828
	Madge	875
C	No. 13	1,002
	No 24	1,028
	Lyline	797
	Etta	972
D	No. 21	1,047
	No 8	1,101
	Maid	785



In 1889 the lot continuously fed on silage made a regular gain, averaging about five pounds per cow per week throughout the eight weeks of the test, and gave at the same time an average of 12.6 pounds of milk per day per cow. In 1890 the lot similarly treated, but fed on less mature silage, lost in weight at the rate of about three pounds per cow per week. In the same tests the lots continuously fed on beets showed an average gain in weight of about two pounds per cow per week in 1889 and four pounds in 1890, although two cows lost weight in 1889 and one remained stationary in 1890.

Considering all the tests we must conclude that a part of the increased live weight shown while feeding on beets was actual gain, but the data are not sufficient to justify an estimate of the average amount of gain. The gains in live weight have been more uniform while feeding on beets, as would be expected from the greater regularity with which the beets were eaten.

WATER DRANK.

Table VII shows the average number of pounds of water drank per cow per day in each lot of cows throughout the two experiments, beginning with February 15, 1891:

TABLE VII.—POUNDS OF WATER DRANK.

Lot.	1891.			1892.			
	Period and food.			Period and food.			
	I.* Beets.	II. Silage.	III.	I. Silage.	II. Beets.	III. Silage.	IV. Beets.
A	45.2	59.4	56.9	58.2	65.8	55.0	57.0
B	52.7	65.7	61.2	63.2	67.2	59.1	66.8
A and B	48.9	62.5	59.0	60.7	66.5	57.0	61.9
	Silage.	Beets.	Silage.	Beets.	Silage.	Beets.	Silage.
C	45.9	48.9	52 4	56.2	53.8	60.8	59.5
D	45.4	47.9	47.6	52.0	46.5	56.3	57.9
C and D	45.6	48.4	49.5	54.1	50.1	58.7	58.7

* Sixteen days.

In 1891 the average amount of water drank was larger while the cows were eating silage, and in 1892 it was larger while they were eating beets. In 1891 there was a general increase in the amount of water drank during the second period, accompanying the generally increased

consumption of food, flow of milk and gain in live weight previously referred to. In 1892 the amount of water drank varies in general harmony with the amount of dry matter consumed in the food. Apparently, the 30 pounds of water found in the daily beet ration in excess of that found in the silage ration has had no proportionate effect in satisfying the desire of the cows for water. In the general average of the two experiments, the cows consumed 127 pounds of food and drink per head per day while on beets and 101 pounds while on silage, a difference of 26 pounds per day. One pound of this may be accounted for in the increased flow of milk and possible gain in live weight while on beets, leaving 25 pounds to be found in the excretions.

RELATIVE DIGESTIBILITY OF THE DRY MATTER OF BEETS AND SILAGE.

As the result of digestion experiments it has been assumed that the dry matter of roots is almost wholly digestible, while from one-fourth to one-third or more of the dry matter of hay, silage and other coarse fodders is found to be indigestible. It is also claimed that roots diminish the digestibility of coarse fodders fed in connection with them. In these experiments no attempt has been made to determine the relative digestibility of the two feeding stuffs under comparison, their relative effectiveness as milk producers being the only point aimed at, and it would seem that a greater relative increase of live weight due to the beets than the experiments seem to indicate must be found before we can safely assume a greater effectiveness for a pound of dry matter in beets than in silage. If the assumption that beets decrease the digestibility of hay, etc., is correct, it amounts to the same thing in practice as though their own dry matter were no more digestible than that of other foods.

THE RELATIVE COST OF BEETS AND CORN SILAGE.

The farm upon which the experiments herein described were made is well adapted to the production of corn, its average yield for the twelve years ending with 1890 being about 57 bushels of shelled corn per acre. Such a crop of grain, with the stalks and leaves carrying it, would contain about 6,000 pounds of dry matter.

On the same land and during the same period the average crops of field beets have amounted to $15\frac{3}{4}$ tons per acre, equivalent to a little more than 3,000 pounds of dry matter per acre. The cost per acre of raising and harvesting the beets has been greater than that of raising and harvesting the corn, so that the dry matter of the beets has cost more than double that of the corn.

At this difference of cost our experiments plainly show that beets cannot be used with economy as a considerable part of a feeding ration.

If they are to be used with profit it must be in small quantity and for the purpose of securing their effect as appetizers.

It must be remembered, however, that these experiments have been made in a region where corn is at its best, but which is considerably south of the latitude best adapted to beets. It is quite probable, therefore, that in more northerly regions the use of beets as compared with silage will be found relatively more profitable than is shown in these tests.

RATIO OF NITROGEN TO CARBON IN FOOD

In planning this experiment the rations were so arranged as to give a wider ratio between the nitrogenous and carbonaceous constituents in the food of lots A and C than in that of lots B and D, but no attempt was made to make a conclusive study of this point, as this would have involved the alternate feeding of these lots and would thus have interfered with the main object of the experiment. The results reached, therefore, must be regarded as of value only when compared with other experiments, planned to illustrate this point chiefly.

In the following table are given the pounds of milk and butter-fat produced by each hundred pounds of dry matter in the food, according as the meal ration was corn meal or the mixture of bran and linseed oil meal, together with the percentage of fat in the milk:

TABLE VIII.—POUNDS OF MILK AND BUTTER FAT AND PERCENTAGE OF BUTTER FAT PRODUCED PER 100 POUNDS OF DRY MATTER IN FOOD

Lots	Meal ration.	Milk.		Butter-fat.		Percentage of fat.	
		1891	1892	1891.	1892	1891	1892.
A and C...	Corn meal.....	69	75	2 44	3 24	3 51	4 29
B and D.....	Bran and oil-meal.....	62	69	2.49	3.18	3.94	4 58

It will be seen that the food having the wider ratio has produced the larger proportionate quantity of milk, in both tests, and that when the ratio was still further increased by the substitution of blue grass hay containing but 8 per cent. protein for clover hay containing 12 per cent. protein, as shown by our analyses, a still larger yield of milk was secured; but it will be observed that although the total quantity of milk has been greater in the case of the cows fed on corn meal, yet the increase of fat has not kept pace with that of milk, the average percentage of fat in the milk in both experiments, and the total quantity of fat in 1891, being relatively smaller in the case of the corn meal fed cows than in that of those fed on bran and oil meal.

It is possible that all the difference here shown may be due to differences in productive power of the different cows One possible cause of such difference at once suggests itself, namely: the length of time since calving. On this point we find that the average time to the middle of the experiment in 1891 was 197 days for lots A and C, and 165 days for lots and D; and in 1892 it was 182 days for lots A and C, and 150 days for lots B and D. In the average of the two experiments it was 189 days for lots A and C and 157 days for lots B and D, a difference which should have had an effect just contrary to that observed.

Neither can this factor account for the superior productiveness of the cows in 1892, for if we exclude cow No 24, which was farrow in 1891 and yet showed a slightly greater productiveness in relation to food consumed than in 1892, we find that the average time since calving was 158 days in 1891 against 169 days in 1892, a difference again contrary to the effect observed. We must therefore conclude either that the blue grass hay, with its smaller proportion of protein, gave a better return than the clover hay, or else that the cows were in better condition for milk production in 1892 than in 1891.

The substitution in 1892 of Etta's Pride and Bacon Maid for Lady Lyle and Misty May was in favor of the later test; but in cases of the grades substituted the average results were in favor of the earlier test.

The average live weights of the ten cows which were used in both tests was greater at the beginning of the test of 1892 than at that of 1891; this was probably the principal cause of the superior productiveness of the food in the latter season.

EFFECT OF WIDE AND NARROW RATIO UPON LIVE WEIGHT.

The alternating periods in these experiments have been found too short to give a trustworthy index to the relative effect of the beets and silage upon the live weight of the cows, but it would seem safe to draw conclusions from periods of twelve weeks continuous feeding, such as we have in the comparison of the corn meal with the bran and oil meal. The results bearing on this point are given below, in a table comparing the average live weight of each lot of cows during the first and last weeks of each experiment:

TABLE IX.—EFFECT OF DIFFERENT MEAL RATIONS ON LIVE WEIGHT, AVERAGE WEIGHT OF COWS AND INCREASE OR DECREASE IN POUNDS.

Lots.	1891.			1892.			Av., 1891 and 1892.		
	First week	Last week.	Increase or decrease	First week.	Last week.	Increase or decrease	First week.	Last week.	Increase or decrease
A	870	870	0	956	976	20	913	923	10
C	837	845	8	933	950	17	885	897	12
A and C	853	857	4	944	963	19	899	910	11
B	854	869	15	963	988	25	908	928	20
D	864	857	—7*	987	969	—18*	925	913	—12*
B and D	859	863	4	975	979	4	917	920	4

* Decrease.

In the average, the cows receiving the corn meal have made the larger gain in live weight, but the difference is too small and too irregular to justify overlooking the factor of individuality, or natural productive capacity, which we will now consider.

II.—THE PRODUCTIVE CAPACITY OF DIFFERENT COWS.

In Table X is given the age of each cow at the time of each experiment, the number of days between last calving and the middle of the experiment, the average live weight during each experiment and the daily gain or loss in live weight, the daily consumption of dry matter, and the pounds of milk and milk fat produced per day and per 100 pounds of dry matter in the food for each test. In estimating the milk fat for 1891 we have used the percentages given by a gravimetric analysis, made April 4th, instead of those given by the Babcock test, for the reason given on page 58. While the insufficiency of a single analysis is fully recognized, it is believed that the error in this case is smaller than that which would follow the using of the other set of co-efficients.

TABLE X.—Productive Capacity of Different Cows.

Breed	Year.	Cow.	Age	Days since calving.	Produced by 100 pounds dry matter in food.		Daily gain or loss in live weight.	
					Milk.	Butter fat.	Gain.	Loss.
			Yrs.		*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Grades	1891	No. 1	7	277	92	3.52	0.300	.....
		" 9	9	142	87	3.19	.....	0.150
		" 20	7	90	83	3.77	.....	0 450
		" 14	9	150	64	3.17	0 300	.. ..
		" [illegible]	7	157	96	3 80	.....	0 212
		" [illegible]	5	452	69	3 08	0.125	. .....
		" [illegible]	9	137	80	3 26	.....	0 675
		" 8	6	233	75	3 12	.....	0 175
		Average	7.4	205	81	3.36	.....	0 117
	1892	No. 25	7	152	95	3 31	.....	0.100
		" 9	10	126	87	3.12	0.500	.....
		" 20	8	90	93	3 23	.....	0.350
		" [illegible]	6	152	76	3.17	0.662	.....
		" [illegible]	9	305	74	3.25	... .	0.250
		" [illegible]	6	126	64	2.82	0.450	.....
		" [illegible]	10	141	77	3.57	.....	0.425
		" 8	7	173	73	3 28	.....	0.475
		Average	7.9	158	80	3.22	0	0
Jerseys	1891	Myrtle	6	127	68	3.76	.....	0.137
		Lady	13	172	40	2.46	0	0
		Cedrica	5	281	54	2.74	0.325	.....
		Madge	5	156	39	2.52	0.225	.....
		Lyline	4	94	65	4.40	0.087	.....
		Regia	4	160	37	2.04	0 412	.....
		Deletta	4	98	52	3 29	0.125	.....
		Misty	4	178	50	3 00	0.262	.....
		Average	5.6	158	51	3.03	0.162	.....
	1892	Myrtle	7	96	78	4.05	0.275	.....
		Regia	5	233	49	2 72	0.462	.....
		Cedrica	6	188	48	2.46	0.625	.....
		Madge	6	186	49	3.18	0.525	.....
		Lyline	5	72	87	4.08	.....	0.187
		Etta	5	349	67	2 61	0 587	.....
		Maid	5	274	63	3.17	0.125	.....
		Average	5.6	200	63	3.19	0.345	.....
		General average	6.6	180	69	3.20	0.090	.....

TABLE X—Concluded.

Breed.	Year	Cow.	Dry matter consumed.		Milk produced per day	Per cent. of fat in milk	Milk-fat produced per day.
			Per day.	Per 1,000 lbs. live weight.			
			Lbs.	*Lbs.*	*Lbs.*	*Per cent.*	*Lbs.*
	1891.	No. 1	26 60	25.58	24.45	3 83	0.936
		" 9	25.80	28.23	22 49	3 66	0.823
		" 20	29.89	29.16	24 82	4 54	1.126
		" 14	28.82	32.15	18 39	4 92	0.904
		" 5	21 55	25.68	20 74	3 95	0.819
		" 24	23.12	26.24	15 97	4.49	0.713
		" 21	26 34	26 68	21 02	4.09	0.860
		" 8	26.45	27.16	19 86	4.16	0.826
Grades		Average	26.03	27.61	20.97	4.18	0.876
	1892	No. 25	25.06	24 57	23 72	3 51	0.833
		" 9	24 61	24 63	21 35	3 57	0 762
		" 20	27.60	25.02	25 65	3 48	0 893
		" 26	25.02	23.06	19.01	4 18	0.795
		" 14	24.69	24.64	18 23	4 40	0.802
		" 24	24.98	24.30	16.05	4 38	0.703
		" 21	25.68	24.52	19 75	4.63	0.914
		" 8	25.34	23.01	18 52	4.51	0.835
		Average	25.37	24.22	20.28	4.02	0 817
	1891.	Myrtle	27.24	33.71	18.43	5.44	1.003
		Lady	23.05	32 51	9.30	6.10	0 567
		Cedrica	25.73	34 91	13.84	5.09	0.704
		Madge	25.31	32.79	9.88	6.45	0.637
		Lyline	22.76	33.08	14.74	6.80	1.002
		Regia	22.23	23 02	8.34	5.45	0.454
		Deletta	19.43	27 25	10 06	6 35	0.639
		Misty	21.37	29.80	10.60	6.05	0 641
Jerseys		Average	23.40	30 88	11.90	5.93	0.706
	1892.	Myrtle	24.91	28.93	19 41	5.17	1.003
		Regia	21.52	21.61	10 47	5 60	0.586
		Cedrica	24.23	29.26	11.68	5.07	0.592
		Madge	24 14	27.59	11.80	6 52	0.769
		Lyline	25.80	32.37	22.41	4.70	1.053
		Etta	27.10	27 88	18.17	3.87	0.703
		Maid	20.82	26.52	13.23	4.97	0.657
		Average	24.07	27.59	15.31	5.00	0.766

In the general summary of Table X we find that the cows averaged about six and one-half years old and had been giving milk for an average of six months at the middle of each test. The average production of milk was sixty-nine pounds for one hundred pounds of dry matter consumed in the food, and the average production of butter-fat was three and one-fifth pounds per hundred pounds of dry matter in the food. Some of the cows lost in live weight while others gained; the average net gain for the thirty-one cows being a little less than one-tenth pound per day.

If we compare the figures giving the production of butter-fat with those showing the gain or loss in live weight we shall find that as a rule the live weight increased when the production of butter-fat fell below the average, and that there was a falling off in live weight when the butter-fat exceeded the average. The exceptions to this rule are chiefly found in the figures for 1891, and there is reason to believe that had the milk analyses in 1891 been as accurate as those in 1892 there would have been fewer exceptions to the rule noted. We find in 1892, however, that the Jersey cow, Myrtle, showed a considerable increase in live weight while producing a considerable excess of butter-fat, and we have no reason to doubt the analysis in this case.

Examining the figures more in detail, we find that eighteen cows showed a gain in live weight, the average gain being 0.354. or one-third pound per cow per day; the butter-fat production of these eighteen cows averaging 3.06 pounds per hundred pounds of dry matter in the food. Twelve cows lost in live weight during the test, the average loss being 0.300 pounds per day, and these cows produced an average of 3.47 pounds of butter-fat for each hundred pounds of dry matter in the food.

The average butter-fat production of all the cows was 3.20 pounds of butter-fat per hundred pounds of dry matter in the food;* but at this rate of production there was a small gain in live weight, hence the average limit of butter-fat production, above which there was a loss in live weight and below which a gain, was somewhat higher than 3.20 pounds per hundred of dry matter. In these experiments this average limit was about 3.25 pounds per hundred of dry matter, although several cows which showed a lower butter-fat production also lost in weight, while the higher production of butter-fat was not always attended with falling off in weight.

In the annual report of the Wisconsin Experiment Station for 1892, page 66, is given a table showing the amount of milk and butter-fat produced by one hundred pounds of dry matter in the food of sixteen cows, mostly grade Jerseys, which had been fed through a total period of thirteen weeks, from December 28, 1891, to March 28, 1892, the daily ration

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The cows consumed an average of 24.68 pounds of dry matter each per day, and the production of butter-fat was 0.792 pounds per cow per day, equivalent to nearly one pound of butter per day, calculating eighty pounds of the dry fat shown by the Babcock test as equivalent to one pound of butter with its normal proportion of water.

consisting of three pounds of ground oats, two pounds of shorts and four pounds of hay per day, with corn silage *ad libitum*. From that table, and from unpublished data kindly furnished by Prof. F. W. Woll, under whose supervision the experiment was executed, we have compiled the following table for comparison with Table X:

TABLE XI.—PRODUCTIVE CAPACITY OF DIFFERENT COWS AT WISCONSIN EXPERIMENT STATION.

Cow.	Age.	Days since calving.	Produced by 100 pounds dry matter in food.		Daily gain or loss in live weight		Breed.
			Milk.	Butter-fat.	Gain.	Loss.	
	Years.	*Days.*	*Pounds*	*Pounds.*	*Pounds*	*Pounds*	
Mattie	10	105	80	2.35	0.389	.....	Grade Holstein.
Emma	10	58	75	3.40	0.022	.....	Grade Jersey.
Palmera	3	113	62	3.23	0 233	.....	"
Rosetta	4	142	36	1.90	0.656	.....	High grade Jersey.
Daisy 2d	6	135	64	3 55	0.778	.....	"
Rue	8	79	55	3.05	0.467	.....	Registered Jersey.
Daisy	10	70	84	4.05	.....	0.122	Grade Jersey.
Bessine	6	24	95	4.70	.....	0 167	High grade Jersey.
Beauty	11	94	80	3.05	.....	0.300	Native.
Bunn	8	147	74	2.30	0.622	.....	Holstein-Jersey.
Gay	9	128	56	2.40	0.367	.....	Grade Jersey.
Galena	8	146	73	3.50	0.378	.....	High grade Jersey.
Sylvia	10	132	67	3.50	.....	0.256	Grade Jersey.
Bessie 2d	6	144	60	3.30	0.300	.....	High grade Jersey.
Sylvan	4	102	45	2.77	0.567	.....	"
Bryant	6	35	98	4.40	0.022	.....	"
Average	7.4	103	69	3.22	0.247	.....	

It appears that one hundred pounds of dry matter in the food produced in the average exactly the same quantity of milk and within six-tenths of one per cent. of the same quantity of butter-fat when fed to these Wisconsin grade Jerseys that it did when fed to our Ohio grade Shorthorns and registered Jerseys; while the average increase in live weight per day of the Wisconsin grade Jerseys was almost identical with that of the Ohio registered Jerseys (see Table VIII). It may be added that the average consumption of dry matter per day in the Wisconsin herd was 24.61 pounds per cow, as against 24.68 pounds in the Ohio herd, the average live weight for the Wisconsin herd being 872 pounds and for the Ohio herd 908 pounds.

It will be observed that twelve of the Wisconsin cows gained in weight during the test, while four lost in weight. The average gain in weight of the twelve cows was 0.400 pound each per day (against 0.354 pound in the Ohio tests), and the average butter-fat production of these twelve cows was 3.01 pounds per hundred pounds of dry matter consumed (against 3.06 pounds in the Ohio tests). Four of the Wisconsin

cows lost in weight at the rate of 0.211 pound each per day, and at the same time produced butter-fat at the rate of 3.82 pounds per hundred pounds of dry matter in the food. Twelve Ohio cows lost in weight at an average rate of 0.300 pound each per day, and deposited butter-fat at the rate of 3.47 pounds per hundred of dry matter. The discrepancy here between the average results of the two tests is greater than at any other point; but if the Jerseys only in the Ohio test were used in the comparison the figures would be 0.162 for loss in weight and 3.92 for production of butter-fat.

In the annual report of the New York State Agricultural Experiment Station for 1891 is recorded the produce during the first period of lactation of fourteen registered cows, including one Holstein-Friesian, four Ayrshires, three Jerseys, two American Holderness, two Guernseys and two Devons. From these records we have compiled the statistics for the ten months following the month in which the calf was dropped, and it appears that the cows consumed on the average 23.70 pounds of dry matter each per day and produced 3.03 pounds of butter-fat per hundred pounds of dry matter in the food. The average age of the cows at beginning of lactation was 821 days and the average live weight was 775 pounds. During the earlier months of this period half the cows lost in live weight; but this loss was gradually regained, and by the tenth month all the cows, except one, were heavier than during the second month, the average gain being at the rate of .28 pound per cow per day over the entire period.

In this experiment the cows were so fed that they received more fat in the food than they produced in the milk; but in the other experiment noted this was not the case.

According to our analyses the average ration fed to our cows in 1892 had the following composition in total dry matter, protein and crude fat:

TABLE XII.—Daily Consumption of Protein and Fat.

Feeding stuff.	Quantity eaten per day.	Total dry matter.	Total protein.	Total fat.
	Pounds.	*Pounds.*	*Pounds*	*Pounds.*
Blue grass hay	14.51	13.64	1.16	0.31
Corn silage	11.96	3.34	0.07	0.11
Mangels	25.00	2.40	0.04	0.04
Meals	6.00	5.30	1.15	0.29
Total	.....	24.68	2.42	0.75

The cows received on the average, therefore, 0.75 pound of crude fat per cow per day in the food, while 0.79 pound per day was found in the milk, the live weight at the same time showing an increase. In other words, more fat was found in the milk than the total quantity given in the food, thus showing that while the fat of the food may be one of the sources of the fat of the milk there must also be other sources. The researches of German experimenters have shown that the protein of the food is one of the chief sources of the fat of the milk, while it is possible that the starchy matters also may be drawn upon in milk-fat production. It would seem reasonable to suppose, however, that the transposition of the fat of the food into milk-fat would take place before the more complex operation of fat formation from other sources would be undertaken, and therefore that a food rich in fat would produce a relatively larger quantity of milk-fat than one deficient in fat.

It happens that most of the feeding stuffs in ordinary use which are rich in protein are also rich in fat, and *vice versa*, a fact which increases the difficulty of determining experimentally which of these two food elements is the more servicable in fat production and at the same time make such determination of less practical value.

III—THE RATIO BETWEEN INCREASE OF LIVE WEIGHT AND PRODUCTION OF BUTTER-FAT.

These experiments clearly show that with the same food and under the same treatment the vital machinery of one cow may transform into butter-fat an amount of fat equivalent to all that is found in the food; another may supplement this with fat previously stored up in the body, and still another may convert into butter-fat other constituents of the food than its fat, while others may divert the fat of the food into the formation of body-fat rather than butter-fat.

In measuring the total efficiency of a food or the total capacity of a cow, therefore, we must find some factor by which the increase of live weight may be compared with the production either of butter-fat or total milk solids, and until it can be demonstrated that one food may be more effective than another in the production of milk as against live weight we must use this factor in calculating the value of a food as a milk producer alone.

These experiments show that such a factor can only be deduced with safety from the study of a very large number of individuals, and this study should include the results of feeding for beef alone, as in such feeding the disturbing factor of milk production is eliminated.

In Table XIII we have compiled the results of such recent experiments in steer feeding as contain the data necessary for comparison with the experiments in cow feeding previously considered:

TABLE XIII.—PRODUCTIVITY OF FOOD IN STEER FEEDING

Station.	Number of steers in test.	Age at end of test.	Gain in live weight.		Reference
			Per day.	Per 100 lbs. dry matter fed.	
		Years	*Pounds*	*Pounds*	
Massachusetts	7	1	1 36	9.24	Ann. Rpts. 1891 & 1892.
"	7	2	1.45	7.65	" "
New York State	5	1½	1.27	11.29	" 1890
Virginia	12	3	2.17	9.26	Bulletin 10.
Ontario	6	2	1.48	11.13	Exp. Farms Rpt 1891.
Kansas	8	3	2.50	10.00	Bulletin 34 and 39.*
Maryland	4	3	2 78	11 60	" 22
Iowa	18	1	2.48	11 35	" 20.†
"	18	2	3.03	9 55	" "
Average				10.06	

* Dry matter estimated from Jenkins and Winton's tables, and comparison made with lots fed on balanced rations only

† Dry matter estimated from Jenkins and Winton's tables. These steers and five of the Massachusetts steers were fed through two successive winters

In the Kansas and Maryland experiments other steers, fed on a less perfect ration, or under exposure to the weather, made a considerably smaller gain than that given in the table, but gain made under such conditions is not comparable with that made by well-sheltered and well-fed cows.

The results of these tests, when examined in detail, indicate as great a range of individuality in beef production as has been shown in milk production, and they forcibly demonstrate the necessity for accumulating a large number of observations before attempting to formulate any general law. In the general average it appears that the increase in live weight per 100 pounds of dry matter fed to steers, has been about three times as great as the production of butter-fat from the same quantity and kind of feed fed to cows giving milk.

This ratio of three pounds increase in live weight to one of butter-fat, must be accepted as true in a general way only. We know that it requires less food to produce a pound of live weight at the beginning than at the end of the fattening period, and in general that the quantity of food required increases with the age of the animal; we know, also, that it requires less food to produce a pound of butter-fat at the beginning than at the end of the period of lactation; we know that there is an increased tendency to substitute flesh production for production of butter-

fat as lactation progresses, but we do not know the ratio in which this substitution takes place. As a contribution to this knowledge the following tables are offered: In Table XIV the thirty-one cows employed in the Wisconsin experiment and the Ohio experiment of 1892 are arranged by classes, according to their distance from calving, and the "total product" is found by estimating the daily gain or loss of live weight on the basis of three pounds to one of butter-fat:

TABLE XIV.—EFFECT OF ADVANCE IN LACTATION ON PRODUCTIVITY OF FOOD

Distance from calving.	No of cows.	Butter-fat per 100 lbs. dry matter.	Live weight		Total per 100 lbs dry matter.
			Gain.	Loss.	
		Pounds.	*Pounds*	*Pounds*	*Pounds*
Less than 60 days, average 39 days	3	4 16	.....	0.04	4.11
60 to 120 days, average 91 days	9	3.32	0.11	.....	3 47
120 to 180 days, average 142 days	13	3 05	0.27	.....	3 41
More than 180 days, average 256 days	6	2.90	0.34	.....	3.35

In Table XV the same cows are arranged by ages, but in this table both Ohio experiments are included:

TABLE XV.—EFFECT OF AGE OF COW ON PRODUCTIVITY OF FOOD.

Age.	No. of cows.	Days since calving.	Butter-fat per 100 lbs. dry matter.	Live weight.		Total product per 100 lbs dry matter.
				Gain.	Loss.	
			Pounds	*Pounds*	*Pounds*	*Pounds*
3 and 4 years	7	127	2.95	33	.....	3 40
5 years	7	260	2.99	23	.....	3 30
6 years	10	135	3.45	29	.....	3 83
7 years	6	157	3 62	.....	11	3.47
8 years	4	115	3.14	28	.....	3.52
9 years	5	172	3.05	.....	12	2.93
10 years	6	105	3.22	.....	9	3.10
11 and 13 years	2	133	2 75	.....	15	2.55

This table indicates a stronger tendency to increase of live weight in the younger cows, and to milk production in those from six to nine years of age, with a decrease in total productiveness after the eighth year.

In Table XVI is given the average record of the fourteen New York cows during the first ten full months of their first milking period:

TABLE XVI.—EFFECT OF ADVANCE IN LACTATION ON PRODUCTIVITY OF FOOD.

Month of lactation	2	3	4	5	6	7	8	9 [1]	10 [2]	11 [3]
Butter-fat per 100 pounds dry matter	*Lbs.* 3 90	*Lbs.* 3 53	*Lbs.* 3 18	*Lbs.* 3.05	*Lbs.* 2.88	*Lbs.* 3.01	*Lbs.* 2.79	*Lbs.* 2 85	*Lbs* 2 77	*Lbs* 2 67
Daily gain or loss (——) in weight	.....	– 37	–.07	.02	.16	.17	.22	.23	.29	.28
Total productivity of food	.....	3.04	3.09	3.08	3.09	3.24	3.08	3.16	3.16	3.04

(1) 13 cows. (2) 12 cows. (3) 10 cows.

It appears that in the case of these young and still growing cows there was an almost exact compensation between the fluctuations in butter-fat production and live-weight increase, on the hypothesis that three pounds of increase in live weight may take the place of one pound production of butter-fat; but the older cows, used in the Wisconsin and Ohio tests, manifest a loss of productiveness of butter-fat as lactation progresses, which is not fully compensated by the increase in live weight, as reckoned on this basis.

In Table XVII we have compiled the general results of the great Chicago test, as published in the *Breeders' Gazette*, using Jenkins and Wintons' averages for determination of dry matter except for corn silage, for which we have estimated 25 per cent. dry matter:

TABLE XVII.—SUMMARY OF THE CHICAGO TEST.

Breed.	Dry matter consumed per day per cow.	Butter-fat produced per day per cow.	Butter-fat per 100 lbs, dry matter.	Gain in live weight per day per cow.	Total product per 100 lbs. dry matter
	Pounds	*Pounds.*	*Pounds*	*Pounds.*	*Pounds.*
Jersey	30.00	1 56	5.20	0 34	5.58
Guernsey	26.70	1.24	4 63	0.21	4.89
Short-horn	31.30	1.12	3.56	1.31	4.95

If we may assume that the difference between Jerseys and Shorthorns lies simply in the kind of product realized from their food, and not in its total quantity, it would seem that the ratio of three pounds increase of live weight to one of butter-fat is too high for comparison in this list. Apparently, the ratio was nearer two to one than three to one.

These cows were in the average about 85 days from calving at the middle of the test, as compared with 103 days for the Wisconsin cows, and 180 days for the Ohio cows.

The two most powerful impulses governing the vital forces are the one which makes for growth until the age of maturity is reached and the one which causes even growth to stop temporarily when lactation begins, and which, under an insufficient supply of food, may cause the previously built up tissues to be drawn upon to the point of emaciation in order to keep up the flow of milk. Table XVI shows how these forces may war against each other, the tendency toward milk production (which is simply a manifestation of the reproductive impulse) for a time overcomes all other forces, and the live weight falls for several months; but finally the two impulses balance each other and then shortly the tendency to growth resumes sway.

In the Wisconsin test the ratio of complete substitution was about three to one. In the average of the two Ohio tests the younger Jerseys showed a more general tendency to increase in live weight than the older grades, but this increase was made at a higher food cost with the Jerseys than with the grades, as the average rate of substitution was about two to one for the Jerseys against twelve to one for the grades Apparently, in dealing with this question we have to deal not only with the impulses towards growth and reproduction, but age and breed are also important factors in determining the ratio between butter-fat production and increase of live weight.

CONCLUSIONS.

The foregoing study of experimental data shows that very great differences may exist between the ability of different animals to utilize the food given them in the production of butter-fat or increase of live weight.

It justifies the expectation, however, that when more complete and perfect data are obtained it will be found that these forms of productive energy may replace each other under a general average ratio of about three pounds of increase in live weight to one pound in yield of butter-fat.

It indicates that this ratio may be temporarily modified by age, by advancement in lactation or in fattening, and by breed; but that the average increase in live weight over the entire period of fattening and the average production of butter-fat through entire periods of lactation, as well as the average gain or loss in live weight during lactation, may be compared upon this basis with a relatively small margin of error.

IV.—POSSIBLE IMPROVEMENTS IN MILK PRODUCTION.

In apportioning the grain and coarser feeds in the rations used in the experiments under consideration, the ordinary practice of farmers and dairymen has been followed of giving the larger proportion of the food in the form of hay and corn fodders, and it is probable that the results indicate very closely the average outcome of this practice, and that it is safe to assume the production of butter-fat for 100 pounds of dry matter fed to the dairy cattle of the country as not exceeding the amount realized in these tests, or three pounds, equivalent to a little less than four pounds of butter.

Two possible lines of improvement on this yield are suggested by these tests: (1) By the selection of cows of greater productive capacity than the average, and (2) by increasing the proportion of fat or protein, one or both, in the food. In the first line much has already been accomplished in the establishment of butter-making breeds; but our experiments show that registry in the herd books is not alone a sufficient guaranty of superiority at the butter tub. In the second line valuable work has been done under the stimulus of competitive dairy tests, but the difficulty encountered here is the great danger of impairing the health of the animal by excessive feeding.

In both these lines the great test at Chicago offers valuable evidence In this test the seventy-four cows were fed for ninety days at the rate of about 29.4 pounds dry matter per cow per day, on which they produced an average yield of 4.45 pounds of butter-fat per hundred pounds of dry matter in the food, and at the same time increased in average live weight at the rate of nearly six-tenths of a pound per cow per day. This is an average increase of nearly fifty per cent. over the results attained in the experiments under consideration, and this increase seems to have been accomplished chiefly through the two lines suggested. The herds of the entire United States and Canada were drawn upon to furnish animals for the test, and the average ration was so proportioned that it contained 1.4 pound of fat and 4.60 pounds of protein per cow per day, or more than double the quantity of each contained in the food consumed by our cows. The total fat given in the food was considerably in excess of that carried off in the milk, whereas in our test and the others noted (except that of the New York station), it was considerably below that quantity. This was accomplished by high feeding on rich grains, the average grain ration per cow per day amounting to 18¼ pounds, containing fully sixteen pounds of dry matter.

The cost of the grains used in this Chicago test averaged nearly fifteen dollars per ton and that of the hay was estimated at ten dollars. The percentage of dry matter in the hay and in the grain was probably approximately the same. On this basis, the cost of 100 pounds of dry matter in the mixed ration as fed at Chicago was about seventy-four cents,

whereas the cost of the same quantity of dry matter fed in the Ohio and Wisconsin tests was about sixty-three cents. If we estimate butter at twenty cents per pound, or butter-fat at twenty-five cents, and increase the live weight at five cents, the total value of the product of 100 pounds of dry matter as fed at Chicago was $1 14, and as fed in Ohio and Wisconsin it was eighty-one cents. The net value, therefore, was forty cents at Chicago and eighteen cents in Ohio and Wisconsin—a difference of more than 100 per cent. in the net profit in favor of the results at Chicago.

There is, however, one other factor which must be considered in comparing the results attained at Chicago with those shown in the other tests under consideration, namely: Distance from calving. In the case of the cows used in the Chicago test the average time between calving and the middle of the test was about eighty-five days, as against 103 days with the Wisconsin cows and 180 days with the Ohio cows

During the first of these periods the Wisconsin cows were approximately the same average distance from calving as those at Chicago, but their average fat product per 100 pounds of dry matter was still nearly thirty per cent. below that at Chicago, and the net profit on their feed was but sixty per cent. of that realized at Chicago.

The Chicago test therefore must stand as a goal of possible achievement far in advance of average results. The experiments here discussed serve to measure the distance between average production and this goal, and at the same time demonstrate the possibility of attaining it, for several cows in the herds under consideration have closely approached the average of the Chicago cows in their work.

PRACTICAL APPLICATIONS AND SUGGESTIONS.

The question of the relative food cost of butter-fat and beef, as applied to the feeding of dairy cows or fattening cattle is one of great importance to the farmer and dairyman; for upon it may depend the entire system of farm management

The question of the play between butter-fat and live weight is perhaps of greater interest to the investigator than to the practical dairyman, although even he cannot afford to be ignorant of the laws governing it. That the investigator cannot afford to ignore it is sufficiently shown by any one of the experiments here quoted, but more conspicuously, perhaps, by the Chicago test than any other. In view of these results it would seem to be a case not admitting of argument that neither a test comparing different foods nor one comparing different breeds can be conclusive unless this factor is given its due weight.

The general average value of this factor, as suggested in preceding pages of this bulletin, must be regarded as tentative only, and subject to the modifications which further experience will dictate. Until the per-

fection of the Babcock method for determining fat in milk, it was practically impossible to accumulate the immense number of observations from which only such a value can be deduced, but with that test at hand and the facilities for chemical analysis now possessed by every experiment station it is not unreasonable to expect that our knowledge on this and similar points will soon be greatly enlarged.

The bulletins of our American experiment stations contain reports of many carefully made experiments in the feeding of dairy cows, but only in those mentioned in this bulletin have we found the complete data necessary for the study of this problem. The Babcock test is being generally used, and percentages and daily yields of butter-fat are becoming abundant; but variations in live weight and composition of food have seldom been reported with the fullness and exactness required for this work. In some cases the variations in live weight have not been observed; in others they have been estimated from single weighings, made one each month; but it is a well established fact that single cows may vary in weight fifty pounds or more between two days, and our experiments show that entire herds may go up and down in the same manner. In some experiments the dry matter in the food is estimated on the basis of Jenkins and Winton's averages instead of special analysis. Undoubtedly these averages are very close approximations to the truth for most feeding stuffs; but in the case of corn silage they are largely based upon the earlier analyses of silage made from immature corn, and they are entirely too low for such silage as is now in most common use—that made from corn carrying a considerable percentage of grain and harvested but little before the point of full maturity. On this point we quote a few of the more recent analyses of corn silage:

TABLE XVIII.—ANALYSES OF CORN SILAGE.

Station.	Publication.	Per cent. dry matter.	Remarks.
New York state.....	Annual Rpt. 1891, p 40...	23.86	Av. of 7 analyses.
Pa. state college	" " p 23...	23 07	" 2 "
University of Wisconsin	" " p. 54...	27.47	.....
" "	" " p. 220..	27.49	.....
" "	" 1892, p. 60...	35.31	Made from mature field corn.....
Ohio State Exp. Sta.....	B, June, 1890, p. 155.....	25.92	Av. of 5 analyses..
" "	Current issue.....	26 33	" 2 "
Jenkins & Winton's av....	U. S. Dpt. Agricult're Ex. Stat. Bull. No. 11	20.90	.....
" " min		12 30	.....
" " max		37.60	....

There is opportunity for wider variation in the percentage of dry matter in silage than in almost any other feeding stuff in common use, and as the dry matter must form the basis of any comparison of foods it is highly important that it be carefully determined.

As we review our own work we regret that the number of analyses, not only of silage but of the other feeding stuffs used, and of the milk, could not have been multiplied many times.

WORK NEEDED.

The experiments under review furnish useful indications on the questions they were designed to illustrate, but their greatest value consists in their demonstration of what is needed in order to increase our fund of exact knowledge.

The necessity for dealing with large numbers of individuals in the study of questions pertaining to animal life and nutrition is exemplified in every test under review. It would seem that experiments including two or three individuals only are scarcely worth the making

The necessity for extending these tests over the longest possible period of time is shown. We need to expand the 90-day test into a 12-month test, and the 12-month test must grow into observations extending over the entire lifetime of a very large number of individuals before perfection in this work is attained. We might as well drop the three or four-week test altogether.

The value of exact chemical analyses is fully shown, and the necessity for endless repetition in such analyses

The relation of meteorological conditions to vital processes needs careful study.

All these points are simply matters of method, the ultimate end of which should be to ascertain the laws under which the vital forces work. To work persistently with this end in view is not at all inconsistent with securing immediate but incidental results of practical application on the farm. On the contrary, the value of these practical results will depend altogether upon the faithfulness with which we follow the scientific ideal.

SUMMARY.

I. Our contrast of corn silage and field beets as food for milk production leads to the following conclusions:

1. The feeding of beets to milk cows has already increased the consumption of other foods and of total dry matter.

2. Beets have always produced an increase in the flow of milk and in the total yield of butter-fat, but this increase has never been sufficient to offset the additional consumption of food.

3. The cows have always shown a greater average live weight while feeding on beets A part of this increase was probably due to increased weight of the contents of the digestive tract, but a part seems to have been actual gain.

4. Beets have not diminished the amount of water drank, although fed in such quantity as to increase the watery contents of the food by thirty pounds per day.

5. Our experiments do not justify the assumption that the dry matter of beets is any more effective as a cattle food, pound for pound, than the dry matter of silage made from well matured corn containing thirteen to eighteen per cent of grain.

6. In the region where the tests were made, and as the average of ten years' culture of corn and beets, side by side, two pounds of dry matter have been produced in the form of corn silage at a less cost than one pound of dry matter in the form of beets.

7. A question which our experiments suggest, but do not answer, is whether beets may be used with any greater advantage in comparatively small quantity and simply as appetizers.

8. While silage made from comparatively mature corn has shown the best results in general, our experiments suggest that the silage should be made before the corn has reached full maturity.

II. The results of our study of the comparative productive capacity of different cows are as follows:

1. When fed a ration composed of about one-fifth to one-fourth grains and the remainder coarse foods of good quality, our cows and those of several other stations have produced an average of about three and one-fifth pounds of butter-fat to each hundred pounds of dry matter in the food, besides making a small gain in live weight.

2. In general, when this rate of production of butter-fat has been exceeded there has been a loss in live weight, and when the butter-fat has fallen below this rate there has been a gain in live weight.

3. Individual exceptions to this general rule show that while some cows may return a handsome profit on their food, others may be fed at an actual loss, even when both butter-fat and increase of live weight are counted at full value.

III. From a comparison of experiments made by several different stations we conclude that in the general average, full periods of fattening

being compared with full periods of lactation, the increase in live weight from a given quantity of food seems to be about three times as great as the average yield of butter-fat from the same quantity of food; and that in the case of cows giving milk, increase in live weight may replace yield of butter-fat in the same general ratio, modified by age, breed and advancement in lactation.

IV. The superior productiveness of individual cows employed in the World's Fair test at Chicago demonstrates the possibility of achieving a great increase in average productiveness through intelligent selection and better feeding.